An equilibrium model of card acceptance*

Elia Moracci
Bank of Italy

Silvio Sorbera
Lear

Preliminary and incomplete
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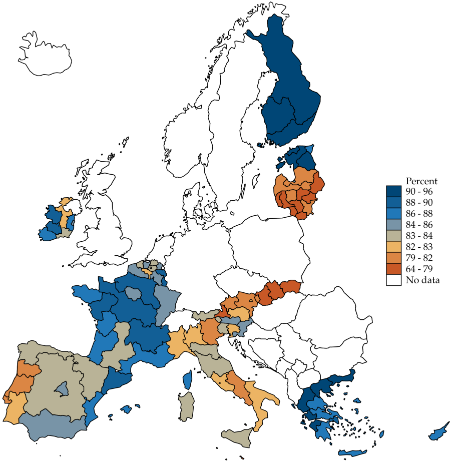
* The views expressed in this paper are solely those of the authors and do not necessarily represent those of the Bank of Italy or Lear.

Card acceptance in the EA

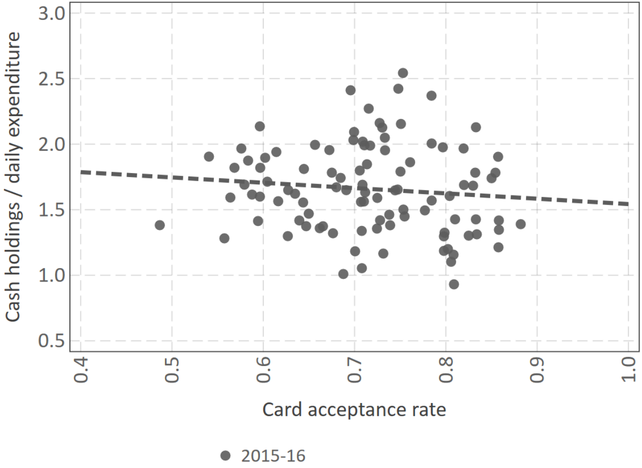
Share of merchants accepting cards varies a lot across EA countries



Note: 2022 data. This graph displays the share of purchases for which card payments were accepted by the merchant, computed using payment diary data.
Source: Survey of the Payment Attitudes of Consumers in the Euro Area, wave 2.

Cash holdings and card acceptance

In equilbrium, card acceptance and cash holdings negatively associated



Note: This graph displays normalized cash holdings (divided by average daily expenditure) across NUTS-2 Euro Area regions, plotted against the share of shops accepting cards in each region. Each point is a region/wave combination.

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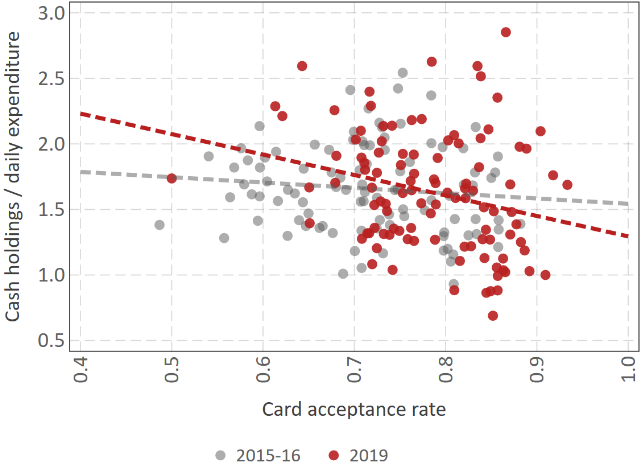

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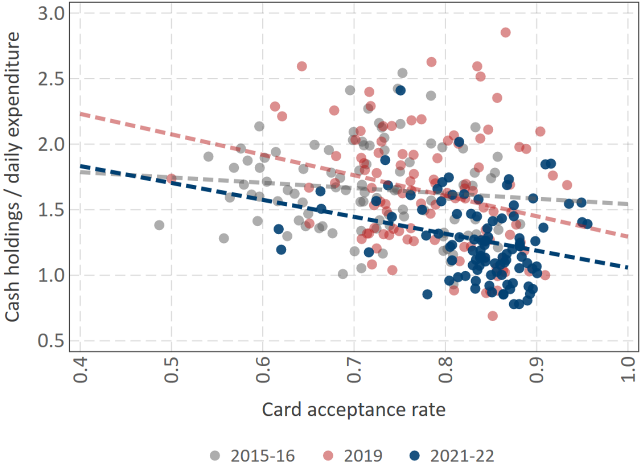

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Equilibrium card acceptance and cash demand

- In areas with high card acceptance, people bring little cash.
  → Not a causal statement, an equilibrium relationship!

- Card acceptance rate are simultaneously determined in equilibrium along with cash holding and payment method choices.
  (Rochet and Tirole, 2003; Huynh, Nicholls, et al., 2022a)

  - If consumers bring little cash, merchants have an incentive to start accepting cards in order to complete transactions.

  - If merchants accept cards more often, the precautionary motive for holding cash fades and cash balances fall.

→ Need to consider buyers' and merchants' problems jointly.

This paper

- We build a stylized model of the payments market that features
  1. strategic interaction among merchants in their card acceptance choices
  2. equilibrium linkages between buyers and sellers.
- **Key trade-off for sellers**: unit profits fall when accepting cards, but more customers visit the store.
  $\rightarrow$ Imperfect acceptance of cards emerges endogenously!
- We derive conditions for existence and uniqueness of equilibria and perform comparative statics.
- We embed the acceptance game in a dynamic model of cash management and payment choices and bring it to the data.

Literature and contribution

- Empirical work on cash usage and card acceptance.
  (Huynh, Schmidt-Dengler, et al., 2014; Arango et al., 2015)

- Models of payment choices and cash management with exogenous card acceptance.
  (Alvarez and Lippi, 2009; Alvarez and Lippi, 2017; Briglevics and Schuh, 2021; Lippi and Moracci, 2024)
  → we endogenize merchant choices

- Models of card acceptance and card usage in the two-sided market for payments.
  (Masters and Rodríguez-Reyes, 2005; Li et al., 2019; Huynh, Nicholls, et al., 2022b)
  → we allow for strategic interactions/competiton among sellers + study cash management

Theoretical model I

Setup

- Two continuums of identical sellers/buyers, each with measure 1.
- Buyers need to purchase a good/service from sellers; value of the purchase is drawn from distribution F.
- A share ω $(1-\omega)$ of buyers prefer using cards (cash) to pay.
- Each buyer is matched to a random seller. With probability α, the buyer is *captive* (Burdett and Judd, 1983), otherwise they can choose a different seller.
- Utility u to both parties when completing a purchase.
- Seller only gets $u-t$ if the purchase is paid for using cards.

Theoretical model II

Choices

- Sellers play a simultaneous move game.
- All sellers accept cash. Each seller decides whether to accept cards or not. Let ϕ be the share of sellers who accept cards. Trade-off:
  - a card transaction delivers $u - t$ instead of u
    card network fee, tax evasion more difficult
  - card acceptance increases sales
    attract customers that prefer cards/don't have enough money
- Buyers have to pay for a purchase of random size $s \sim F$. Before knowing s, they choose how much cash to hold $m^*(\phi)$.
  - Agents always pay with their preferred payment method if they have the chance.
  - After observing the size of the purchase s, if they are not captive they can choose to pick a store that accepts cards.

- A share $1-\omega$ of buyers (preferring cash payments, type c) solves

$$m_c^*(\phi) = \arg\min_m \quad Rm + \alpha\,(1-F(m))\,(\phi\kappa + (1-\phi)u) + (1-\alpha)\,(1-F(m))\,\kappa,$$

where κ is the cost of paying with least preferred payment method and R is the opportunity cost of holding cash.

- A share ω of buyers (preferring card payments, type d) solves

$$m_d^*(\phi) = \arg\min_m \quad Rm + \alpha(1-\phi)\,(F(m)\kappa + (1-F(m))\,u)\,.$$

Buyers

Optimal cash holdings

- If $\phi > 0$, optimal cash holdings are given by

$$m_c^*(\phi) = f^{-1}\left(\frac{R}{u-(u-\kappa)\left(\alpha\phi+(1-\alpha)\right)}\right),$$
$$m_d^*(\phi) = f^{-1}\left(\frac{R}{\alpha(1-\phi)(u-\kappa)}\right).$$

  - $m_c^*(\phi) \geq m_d^*(\phi)$ for any ϕ;
  - cash demand is decreasing in R and ϕ;
  - $m_c^*(1) > 0$.

Seller's problem

- Let $\Phi_i \in \{0,1\}$ denote the acceptance decision of each seller
  $\Phi_i = 1 \rightarrow i$ accepts cards
- Optimal choice of seller i is given by

$$\Phi_i^*(\phi) = \arg\max_{\Phi_i} (1-\Phi_i)\,\Pi_i^c(\phi) + \Phi_i \Pi_i^{cd}(\phi),$$

- Expected profit if seller i accepts cash only

$$\Pi_i^c(\phi) = \ (1-\omega)F(m_c^*(\phi))u + \omega\alpha F(m_d^*(\phi))u.$$

- Expected profit if seller i accepts cash + cards

$$\begin{aligned}\Pi_i^{cd}(\phi_{-i}) = \ & (1-\omega)\,F\left(m_c^*\left(\phi\right)\right)u \\ & + (1-\omega)\underbrace{\left(1-F\left(m_c^*\left(\phi\right)\right)\right)}_{\text{More transactions}}(u-t)\left(\alpha+(1-\alpha)\phi^{-1}\right) \\ & + \omega \underbrace{(u-t)}_{\text{Lower unit profits}} \left(\alpha + \underbrace{(1-\alpha)\phi^{-1}}_{\text{More clients}}\right)\end{aligned}$$

Timing and equilibrium

Sellers' acceptance choices	Aggregation	Buyers' cash holding choices	Equilibrium
Seller i solves $\max_{\Phi_i} \Phi_i \Pi_i^{cd}(\phi) + (1-\Phi_i)\Pi_i^c(\phi)$ Best response $\Phi_i(\phi)$	Let $\phi = \int_0^1 \Phi_i di$ cashless acceptance rate	Buyers of type $j \in \{c, d\}$ solve the problem $\max_m vj(m, \phi)$ Cash demand $m_j^*(\phi)$	Tuple of acceptance and cash demand (ϕ^*, m^*) such that $\phi^* = \int_0^1 \Phi_i(\phi^*)di$ $m_j^* = \arg\max_m v_j(m, \phi^*), \forall j$

Note: Sellers optimally respond to their competitors' acceptance choices. Buyers observe the cashless acceptance rate and hold an amount m^* accordingly. In equilibrium, i) each seller has no incentive to deviate given the actions of the other sellers and given money demand m^* by buyers, and ii) money demand is optimal given the aggregate acceptance rate ϕ^*. Let $j \in \{c, cd\}$ denote buyers' types, defined according to their payment preferences.

Types of equilibrium

- Consider the *net benefit of accepting cards*

$$\Delta_i(\phi) = \Pi_i^{cd}(\phi) - \Pi_i^{c}(\phi).$$

$\rightarrow$ *Pure cash* equilibrium $\phi^* = 0$: $\Delta_i(0) < 0$

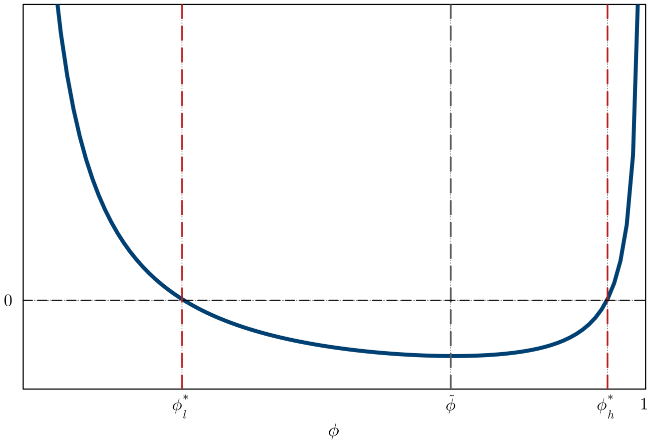
$\rightarrow$ *Full acceptance* equilibrium $\phi^* = 1$: $\Delta_i(1) \geq 0$

$\rightarrow$ *Imperfect acceptance* equilibrium $\phi^* \in (0, 1)$:

$$\Delta_i(\phi^*) = 0,$$

Graphical depiction of $\Delta_i(\phi)$

Strategic complements/substitutes: congestion vs coordination



Note: The above Figure displays the function $\Delta_i(\phi)$ for $\phi \in [0.01, 1]$. The red lines mark the imperfect acceptance equilibria (ϕ_l^*, ϕ_h^*). Notice that $\phi^* = 1$ is also an equilibrium of the model. F is an exponential distribution with parameter $\lambda = 2$. Other parameters are $u = 1$, $\kappa = 0.03$, $R = 0.025$, $t = 0.5$, $\alpha = 0.8$, $\omega = 0.3$.

Results I
Equilibrium

- **Existence:** at least one equlibrium exists.
- **Number and features of equilibria.**
  - The pure cash economy with $\phi = 0$ is not an equilibrium of the model.
  - If $F \sim \mathrm{Exp}(\lambda)$ there are at most three equilibria: the full acceptance equilibrium $\phi^* = 1$ and either zero or two imperfect acceptance equilibria (ϕ_l^*, ϕ_h^*), with $\phi_l^* < \phi_h^*$.
  - Only the full acceptance and the imperfect acceptance equilibrium ϕ_l^* are stable under best-response dynamics.

Results II

Comparative statics

- As search frictions increase ($\alpha \uparrow$), less sellers accept in equilibrium.

- As the share of agents preferring cards increase ($\omega \uparrow$), less sellers accept in equilibrium.
  Somewhat counter-intuitive, happens because at the equilibrium acceptance rate the larger increase in the client base from accepting as ω rises is more than offset by the higher fees paid

- As the opportunity cost of holding cash rises ($R \uparrow$), more sellers accept in equilibrium.

An application

Implications for models of payment choices and cash management

- We embed the acceptance game in otherwise standard dynamic model of cash management and payment choices by households, which we then calibrate using payment diaries for the Euro area.

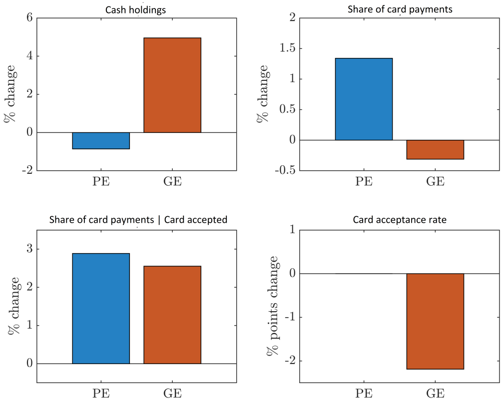
- We study the effects of a policy that makes card usage more convenient for buyers, under two settings:

  - **Partial equilibrium.** We assume that ϕ^* is fixed and that only household choices respond to the policy change.

  - **General equilibrium.** We allow sellers to re-optimize and derive a new ϕ^* after the policy change, which in turn affects households' choices.

An application

Implications for models of payment choices and cash management



Note: The above Figure displays the changes in M/e, γ, $\widetilde{\gamma}$ and in the equilibrium acceptance rate ϕ when introducing a card subsidy of value $\xi = 0.1\kappa$, both in a partial equilibrium setting (keeping ϕ fixed and simply solving again the buyer's problem), and in a general equilibrium setting in which we allow sellers to respond optimally by adjusting their acceptance policies, possibly affecting ϕ.

Going forward

- Estimate our quantitative model at the region $\times$ wave $\times$ store type level, to study drivers of differences in card acceptance across space, time and sectors.

- Use the model to answer some questions:

  1. what is the impact of a subsidy to card acceptance? how large should it be to reach full acceptance?

  2. how costly is imperfect acceptance for buyers?

- **Extensions:**

  - Price discrimination based on acceptance
    surcharging: stores that accept cards post higher prices

Thank you for your attention!

email me at elia.moracci@bancaditalia.it
comments/suggestions/criticism welcome

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